

Identifying A-stars in the CoRoT-fields IRa01, LRa01, LRa02

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Abstract. Up to now, planet search programs have concentrated on main sequence stars later than spectral type F5. However, identifying planets of early type stars would be interesting. For example, the mass loss of planets orbiting early and late type stars is different because of the differences of the EUV and X-ray radiation of the host stars. As an initial step, we carried out a program to identify suitable A-stars in the CoRoT fields using spectra taken with the AAOmega spectrograph. In total we identified 562 A-stars in IRa01, LRa01, and LRa02.

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INTRODUCTION

CoRoT is a satellite mission launched in December 2006. It is specialized on the detection of extrasolar planets and for studying the pulsations of stars by means of ultra-precise photometric measurements. The photometric accuracy achieved is 10 to 100 times better than what be achieved from the ground (10^{-4} in the exoplanet channel). In the so-called long runs, the fields are observed continuously for 150 days. About 500 stars are observed with the full sampling rate of 32 seconds in the exoplanet channel. All other stars, typically about 6000, are observed with a sampling rate of 8.5 minutes. Up to now, CoRoT has discovered more than 15 extrasolar planets. Amongst them is the first transiting rocky planet found outside the solar system (CoRoT-7b), a planet of a young, active star (CoRoT-2b), a temperate planet (CoRoT-9b), and the first transiting brown dwarf orbiting a normal star (CoRoT-3b). The CoRoT objects open up a new window for studying extrasolar planets. However, the host stars of all these planets are F, G, and K-stars.

As outlined in detail in Guenther et al. (2010) it would be very interesting to detect planets of earlier type stars. For example, the mass loss of planets orbiting early and late type stars is different because of the differences in the EUV and X-ray radiation of the host stars. By comparing the properties of planets orbiting A-stars and late-type stars, we can find out what the influence of the central star for the planet is. However, detecting planets of A-type stars by means of transit observations is difficult, because the transits are shallower than for smaller stars. Additionally, many A-stars oscillate, which makes the analysis of the light curves rather difficult. In order to make progress in this field of research it is thus essential to identify the A-star first. This is the aim of this work.

IDENTIFYING CANDIDATES AND OBSERVATIONS

Prior to the launch of the satellite, many CoRoT fields were observed using multi-colour photometry (B, V, R, I). Almost all stars that CoRoT observed are also in the 2MASS data-base, so that J, H, K magnitudes are available. The whole photometric data is accessible through EXODAT (Deleuil et al. 2006).

However, identifying A-type stars only on the basis of the broad-band photometry is difficult because of the reddening. We thus take a two-step approach. In the first step we pre-select the stars based on photometry. As a criterion we use the $B-V$ colors, and select all stars with $B-V = -0.16^m$ to 0.42^m , corresponding to an un-reddened B5V to F5V star (Binney & Merrifield 1998). The second step is then the proper determination of the spectral types based on spectroscopy. While the colour-selection approach reduces dramatically the number of stars that we have to study, we may loose a few highly reddened A-stars in this process. Thus, our survey does not aim at detecting *all* A-stars observed by CoRoT but it aims at finding a sample of A-stars that can be studied.

Although we preselected the targets, we still have to take spectra of several hundred stars. Luckily, as part of the ground-based follow-up observations the CoRoT fields IRa01, LRa01, and LRa02 were observed with the multi-object spectrograph AAOmega mounted on the AAT (Anglo-Australian-Telescope when the observations were taken, now renamed to Australian-Astronomical-Telescope). AAOmega is ideal for our purposes, as this instrument allows to take spectra with up to 350 stars in a field of $2^\circ \times 2^\circ$ (Saunders et al. 2004; Smith et al. 2004). The CoRoT fields IRa01 and LRa01 have a size of $1.4^\circ \times 2.8^\circ$, and LRa02 $1.4^\circ \times 1.4^\circ$. Mounted in the prime focus of this telescope is a fibre positioned that feeds the AAOmega spectrograph. Using the AAT together with the AAOmega spectrograph we have obtained more than 20 000 spectra of stars in the CoRoT-fields.

IRa01, LRa01, and LRa02 are located in the so-called anti-center “eye” of the CoRoT-mission (RA 6h to 7h and DEC -10° to 10°). The data was obtained in two campaigns. The first campaign was carried out from the 13th to the 20th of January 2008. Unfortunately, observations could only be obtained on the 13th and 14th of January. Nevertheless, 4112 spectra of stars in IRa01 and LRa01 were taken. The second campaign was carried out from the 28th of December 2008 to the 4th of January 2009. Observations were carried out in all eight nights, and we took spectra of 14187 stars in all three fields.

We used “Configure”, the target allocation software in order to find the optimum configuration of the fibres. In each setting we typically managed to place 350 fibres onto target stars, and 25 fibres onto the sky background. In order to optimize the exposure time we minimized the spread in brightness of the stars observed in each setting. We started our observations with the fields containing the brightest stars and subsequently used setting of fainter stars.

Our targets have V-magnitudes in the range 10 to 15, corresponding to the bright part of the CoRoT/Exoplanet targets. Down to $m_V = 14.5$, our observation cover essentially all stars in the CoRoT-fields.

As usual, a fibre bundle was placed onto a relatively bright star for guiding purposes. In order to monitor any possible field rotation, typically 6 fibres were place onto stars within the FOB. For the observations we used the AAOmega spectrograph with the 580V grating in the blue arm and the 385R in the red arm. The spectra cover the spectral range

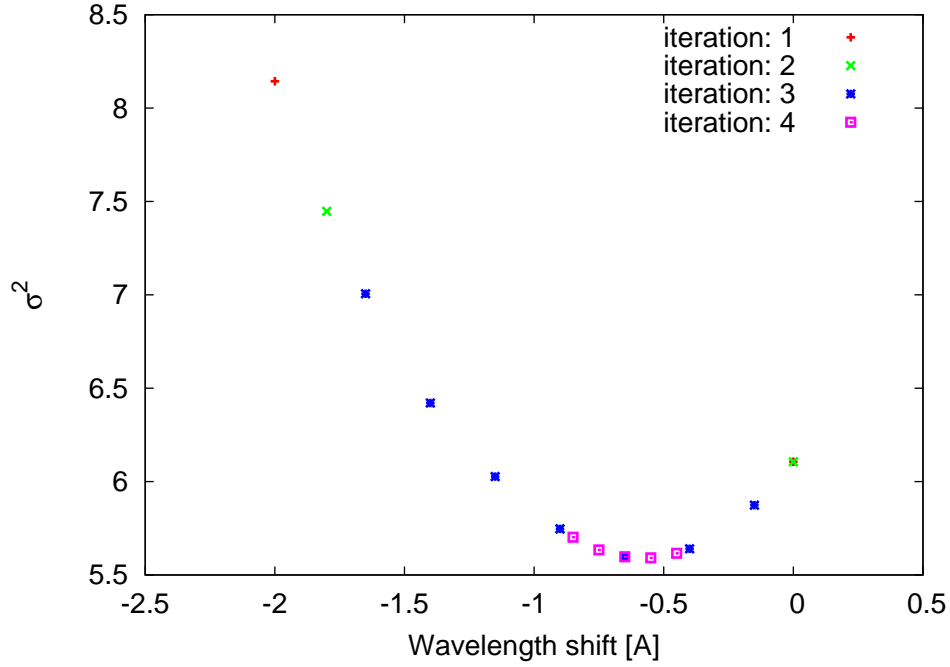


FIGURE 1. The spectral types are obtained iteratively by fitting the observed spectra to templates by minimizing σ^2 . Shown here is the derived σ^2 vs. the shift in wavelength. The best match is obtained at the minimum of σ^2 .

from 3740 to 5810 Å in the blue arm, and 5650 to 8770 Å in the red arm. The resolution is $R=1300$.

Each field was observed for 30 to 45 minutes. In order to avoid any saturation, and in order to make the removal of cosmic rays easy, we split the observing time spend on each field into three or more exposures.

All calibration frames (flat, arcs and bias-frames) were taken as it is common practice with AAOmega: Bias frames in the afternoon before each observing night, flats and arcs before the observations of each field. The sky subtraction is not critical, because we observed only stars brighter than 15.0 mag and the observations were carried out during dark time. Nevertheless, for subtracting the spectrum of the night sky from the stellar spectra, we have to calibrate the relative throughput for each fibre. Because the throughput varies depending on the bending of the fibre, these measurements had to be done after the fibres have been positioned. The throughput of each individual fibre was determined by taking spectra during dawn, or observing fields of blank sky during the night. The spectra were reduced using the 2dfrdr-reduction package which has especially been developed for AAOmega.

HOW THE SPECTRAL TYPES ARE DETERMINED

As outlined above, we take a two-step approach. In the first step. we select suitable candidates based on their $B-V$ colours. The second step then is the determination of the

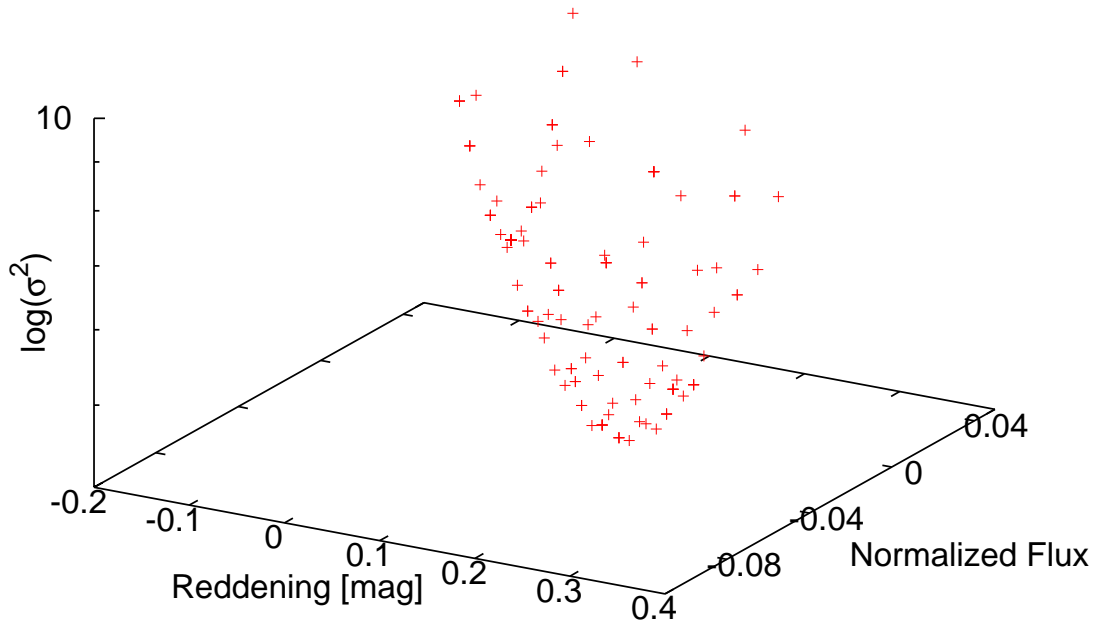


FIGURE 2. Same as Fig. 1 but for the flux and the reddening.

spectral type using the AAOmega observations.

This is done by deriving which spectrum from a library of template spectra matches best the observed spectrum. We use *The Indo-U.S. Library of Coudé Feed Stellar Spectra* (Valdes et al. 2004) for this purpose. For each template σ^2 is calculated as the sum of the squared differences between the template and the observed spectrum. In order to match each template to the observed spectrum, we first shift the spectrum to the correct position in wavelength, adjust the flux, and remove the extinction. This process is done iteratively, always by varying each of these parameters and then minimizing σ^2 . In this way we automatically determine the radial velocity and the extinction A_V (Binney & Merrifield 1998; Figs. 1, 2) for each star. Since the library includes templates of different luminosity classes, we can also determine the luminosity class for the star (Fig. 3).

THE ACCURACY OF THE METHOD

Figure 4 shows an observed spectrum together with the best matching template. The red line is the observed spectrum of the star after correcting it for extinction, radial velocity, and removing also the off-set in flux. The green line is the template spectrum of an A5V star. The templates matches the observed spectrum extremely well.

The question however is, how accurate the method for determining the spectral types is. For 178 stars, we have obtained several spectra. This data thus allows a thorough test how accurate our method is. In these cases, we derive the spectral type of the same star several times using different spectra. The differences of the spectral types derived for the same star thus gives us the error of the measurements. The result is shown in Fig. 5.

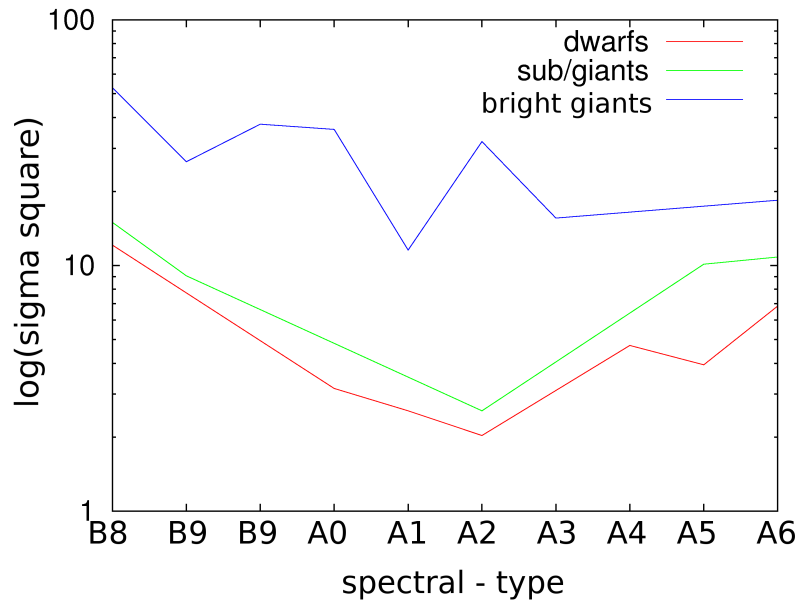


FIGURE 3. Shown is the differences between the templates and the observed spectrum expressed in σ^2 for templates of different spectral types and luminosity classes. The minimum of σ^2 is achieved for A2V.

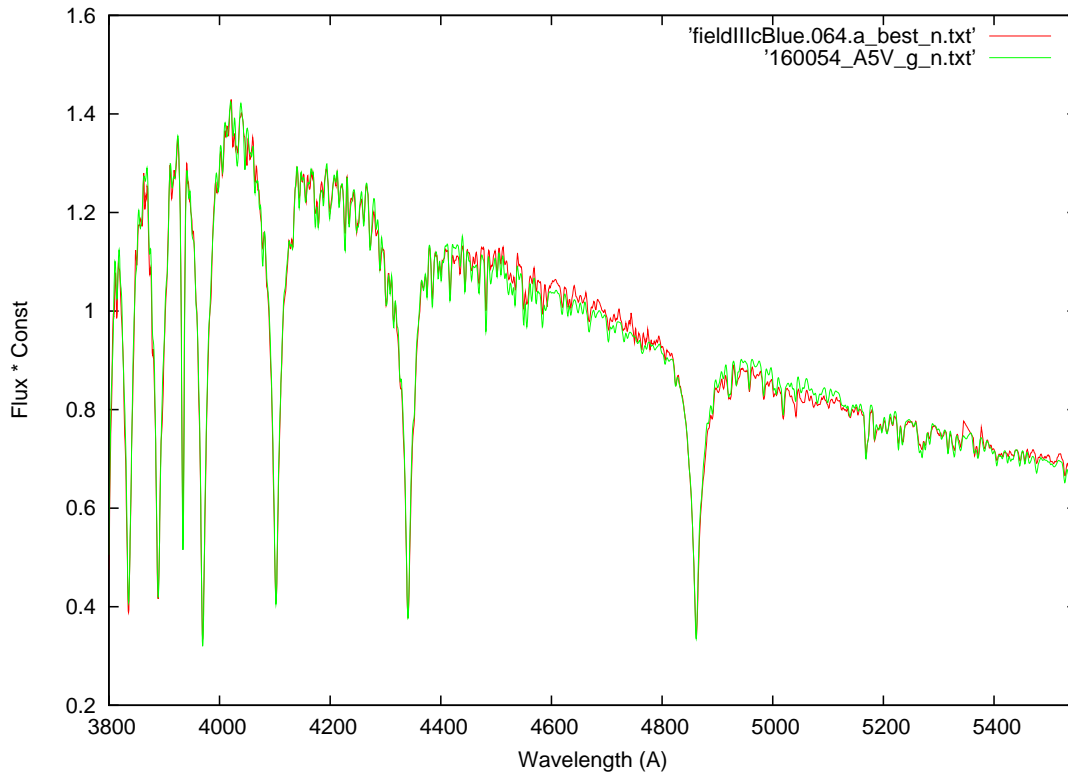


FIGURE 4. Observed spectrum (red line) and the best matching template (green line) for an A5-star.

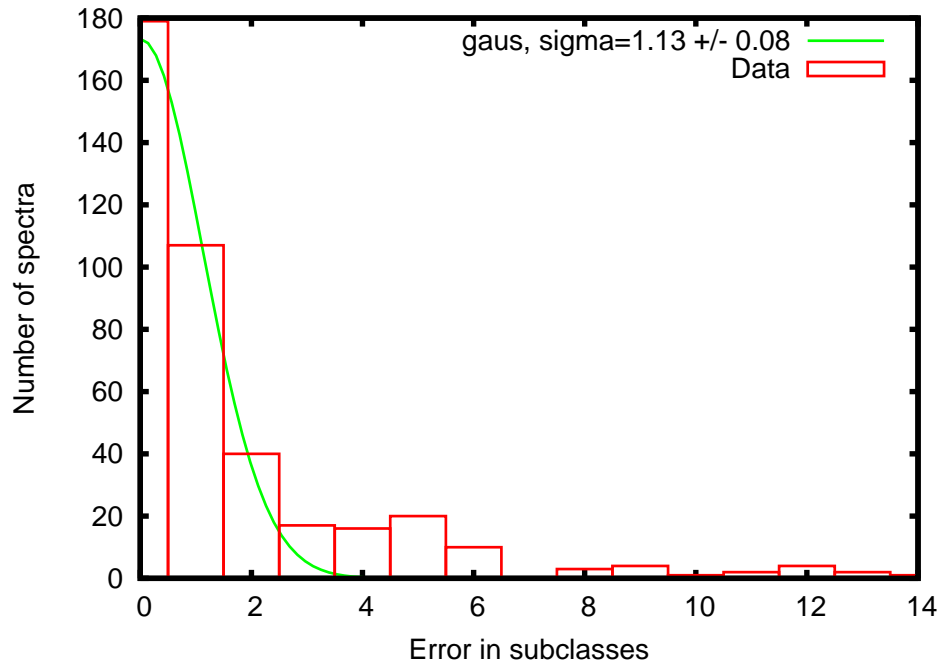


FIGURE 5. The error in subclasses, derived from the difference of the spectral types obtained for stars of which several spectra were taken.

A value of 1.0 means that the difference of the spectral type of two determinations of the same star is one subclass. We find that our error is 1.13 ± 0.08 subclasses. As can be seen in Fig. 5, there are a few outliers. These are largely due to the fact that a few individual spectra were affected by instrumental problems. As shown in Fig. 3, we can also reliably distinguish between dwarfs and giants. Since the difference between dwarfs and sub-giants is rather small, distinguishing these is less certain.

It turns out that the main limitation of the determination of the spectral types is not the quality of the spectra, or the analysis of the data, but the quality of the templates taken from the literature. The libraries published by different authors gave slightly different results (Le Borgne et al. 2000, and Jacoby et al. 1984).

THE SPECTRAL TYPES DERIVED

As already mentioned above, we selected stars according to their $B-V$ colours. As a selection criteria, we used $B-V = -0.16^m$ to 0.42^m , corresponding to an un-reddened B5V to F5V stars (Binney & Merrifield 1998). In total 805 stars were observed with AAOmega which matched this criterion. After the detailed analysis of the spectra we identified 562 A-stars in IRa01, LRa01, and LRa02. Thus, $\sim 70\%$ of the stars in the range between $B-V = -0.16^m$ and 0.42^m are A-stars. Figure 6 shows the distribution of spectral types. An interesting feature is that stars with spectral types of A3V and A4V are missing. This does not mean that stars of a certain temperature do not exist but it means that almost no stars match the A3V and A4V templates from the literature. This

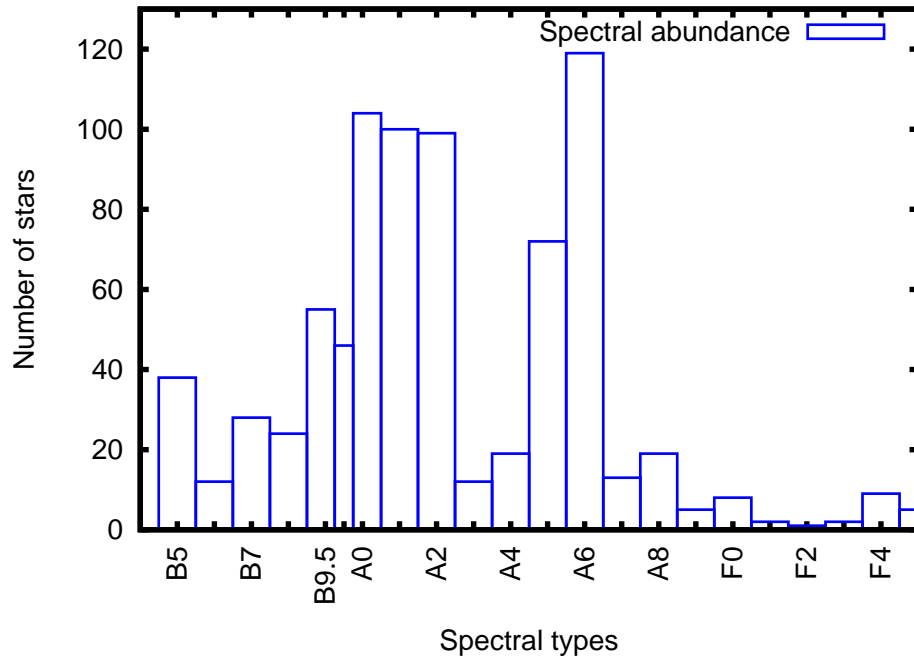


FIGURE 6. Distribution of spectral types in our sample.

is caused by the slightly odd definition of the sub-classes in this spectral regime. The absence of these types of stars is already well known.

After identifying 562 A-stars in IRa01, LRA01, and LRA02, we now intend to analyze the CoRoT light-curves of these stars in detail in order to detect the shallow transits of planets orbiting these stars.

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